Original communication

INCIDENCE OF ATLAS BRIDGES AND TUNNELS – THEIR PHYLOGENY, ONTOGENY AND CLINICAL IMPLICATIONS

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RESUMEN

En la vértebra atlas, los puentes posteriores, los puentes laterales y los túneles postero-laterales son las protrusiones óseas que pueden causar presión externa en la arteria vertebral cuando pasa del foramen transverso de la vértebra cervical al foramen magnum del cráneo. Ejemplares que muestran dichas protrusiones fueron clasificadas según tengan puentes del atlas completos o incompletos que pueden predisponer a la insuficiencia vertebrobasilar y al síndrome cervicogénico especialmente durante los movimientos de cuello. El objetivo del estudio es saber la incidencia, ontogenia y filogenia de los puentes del atlas junto con las implicaciones clínicas. Este canal de la arteria vertebral del atlas y la morfología de los puentes fueron estudiados en un total de 60 (120 lados) vértebras atlas humanas completas y secas obtenidas de la colección de esqueletos del Departamento de Anatomía del Government Medical College de Amritsar en Punjab. La incidencia de la impresión de la arteria vertebral (44), la impresión profunda de la arteria vertebral (42) era 71,66%, el puente parcial fue 13,33% y el puente lateral parcial fue 3,33% en el lado derecho y 5% en lado izquierdo. También se observaron doce anillos completos y un túnel 1.66% postero-lateral. La ocurrencia de estos puentes óseos abrazando la arteria vertebral es de suma importancia clínica, pueden causar efecto de comprensión en la arteria vertebral durante la rotación extrema de la cabeza y movimientos de cuello manifestándose en mareos, desmayos, diplopía temporal, vértigo y desórdenes neurológicos. El conocimiento de esta variación es importante para médicos, otorrinolaringólogos, neurólogos y ortopedistas que en la práctica diaria están en contacto con estas enfermedades de la columna vertebral y sus consecuencias.

***Palabras clave**: Puentes del atlas, foramen arqueado, puentes, arteria vertebral.*

ABSTRACT

In atlas vertebrae, the posterior bridges, lateral bridges and postero-lateral tunnels are the bony outgrowths which may cause external pressure on the vertebral artery when it passes from foramen transversarium of the cervical vertebra to foramen magnum of the skull. Specimens exhibiting such outgrowths were classified as having incomplete or complete atlas bridges that may predispose to vertebro-basilar insufficiency and cervicogenic syndrome especially in neck movements. The objective of the study is to know the incidence, ontogeny and phylogeny of atlas bridges along with its clinical implications. The groove of the vertebral artery of the atlas and the morphology of the bridges were studied in a total of 60 (120 sides) complete and dry human atlas vertebrae obtained from the skeletal collection of Department of Anatomy, Government Medical College, Amritsar, Punjab. The incidence of impression of vertebral artery (44), deep impression of vertebral artery (42) was 71.66%, Partial ponticuli were 13.33% and Partial lateral ponticuli were 3.33% on right side and 5% on left side. Twelve complete rings and one 1.66% postero-latetal tunnel was also observed. Occurrence of these bony bridges embracing the vertebral artery is of great clinical importance, may cause compression effect on the vertebral artery during extreme rotation of head and neck movements presenting with dizziness, fainting, transient diplopia, vertigo and neurological disturbances. The knowledge of this variation is important for physicians, otolaryngologists, neurologists and orthopaedicians who in every day practice are in contact with the diseases of spine and their consequences.

***Key words**: Atlas bridges, arcuate foramen, ponticuli, vertebral artery.*

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INTRODUCTION

In human atlas vertebrae, the superior aspect of posterior arch of atlas is characterized by a groove known as sulcus arteriae vertebralis for the passage of vertebral artery and suboccipital nerve. The groove may be shallow, deep or at times, bony outgrowths known as atlas bridges may develop over this segment. These bridges may indicate anomalous ossification of the groove by oblique ligament of atlas; a fibrous tissue present at the lower border of posterior atlanto-occipital membrane converting the groove to form a complete or incomplete bony ring (William et al, 1995).

The occurrence of this bony bridge has been well documented in the literature (Allen, 1879; Cleland, 1860) where it has been variously described as foramen sagittale atlantis, foramen atlantoideum posterior, kimmerle variant,foramen atlantoideum vertebrale, foramen retroarticulare superior, canalis arteriae vertebralis, arcuate foramen, retrocondylar vertebral artery ring, ponticulus posterior, retroarticular canal, pons ponticus, posterior glenoid process and speculum (Hasan et al, 2001).

Ponticulus posticus (posterior bridge) and Ponticulus lateralis (lateral bridge) are the two kinds of bridges and sometimes a combination of these two for example ponticulus posterolateralis is also present. The posterior bridge is an osseous bridge that is formed between the posterior margin of superior articular facets and the posterior arch of the atlas and when complete forms the retroarticular canal. Whereas the lateral bridge is a lateral outgrowth of bone that bridges the lateral margin of the superior articular facets to posterior root of transverse process of the atlas and may exist as supra-transverse foramen. In ponticulus posterolateralis, a wide bony fragment extends from the lateral margin of posterior one third of superior articular facet to the transverse process and dorsal edge of the vertebral groove of the atlas (Mitchell, 1998a; Hasan et al, 2001).

The vertebral artery is most vulnerable for compression during extreme rotation of head and neck movements presenting with dizziness fainting and transient diplopia. Occurrence of these bridges may further compromise the caliber of already stretched vertebral artery (Hasan et al, 2001). Cushing et al (2001) found an association between the arcuate foramen and tethering of vertebral artery in it, leading to its dissection from repetitive trauma with movement of neck. Tubbs et al (2007) emphasised that bony bridge forming arcuate foramen may cause external pressure on the vertebral artery as the later passes through it to the foramen magnum. Thus this anatomical variation of atlas bridging draws attention and may facilitate interpretation of radiological findings, guide certain neurosurgical interventions, note of caution when cranio-vertebral manifestations are carried out.

MATERIALS AND METHODS

A total of 60 (120 sides) complete dry human atlas vertebrae obtained from the skeletal collection from the Department of Anatomy, Government Medical College, Amritsar, Punjab. All the vertebrae were undamaged, thoroughly boiled, cleaned and numbered from 1-60 each. The posterior arch of atlas vertebrae was examined for the evidence of exostosis from posterior margin of superior articular facet and the specimens exhibiting such bony outgrowths were classified as having either a complete or incomplete bony ring. The morphology of atlas bridges i.e. posterior bridge, lateral bridge and posterolateral tunnels was studied and observations thus were made on the variability of sulcus/canalis arteriae vertebralis for example vertebral arterial grooves on all the atlas vertebrae following the criteria used by Mitchell (1998a) and Hasan et al (2001) and statistical analysis was also done.

According to Mitchell (1998a, b) there are 3 classes of posterior bridge as: Class I - Groove of vertebral artery, Class II - Retroarticular sulcus showing incomplete ring with middle part missing which is formed by exostosis (bony lipping) of posterior border of lateral mass and posterior arch of atlas, Class III - Retroarticular canal showing a complete bony ring enclosing the vertebral artery. Lateral bridge shows complete ring incomplete rings

According to Hasan et al (2001) there are 6 classes as: Class I - only the impression of vertebral artery on posterior arch of atlas, Class II - when this impression becomes deeper then becomes groove i.e. Deep groove for vertebral artery, Class III - Partial posterior ponticulus as a bony spicule extending from the superior articular facet overhanging the dorsal arch, Class IV - Complete posterior ponticulus, Class V - Partial lateral ponticulus extended from the lateral mass to the transverse process, Class VI -Partial postero-lateral tunnel

RESULTS

The groove of vertebral artery (44) and the deep groove of vertebral artery (42) was found to be

71.66% (Figure 1A, B), out of which groove of vertebral artery as 4 (6.66%) on right side, 4 (6.66%) on left side and18 (30%) bilateral and deep groove of the vertebral artery 8 (13.33%) on right side, 6 (10%) on left side and 14 (23.33%) bilateral was also observed.

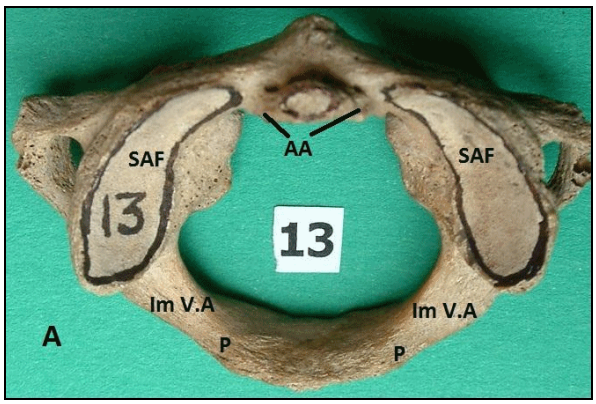

Figure 1A- Groove of vertebral artery. SAF- Superior Articular Facet, AA- Anterior Arch, P- Posterior Arch, Im V.A- Impression Vertebral Artery.

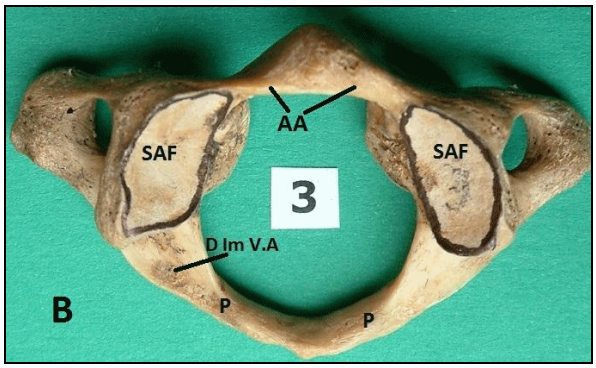

Figure 1B- Deep groove of vertebral artery. SAF- Superior Articular Facet, AA- Anterior Arch, P- Posterior Arch, D Im V.A- Deep Impression Vertebral artery.

The partial (incomplete) ponticulus (Figure 2A) was found to be 13.33% out of which the incomplete ring was seen in 2 (3.33%) cases on right side, 2 cases (3.33%) on left side and 6 (10%) cases were bilateral.
The complete ponticulus (Figure 2B) was seen in 3(5%) case on right side, 5(8.33%) cases on left side and 2 (3.33%) were bilateral. Thus out of 12(10%) complete rings we found 3(25%) case on right side, 5 (41.66%) cases on left side and 2 (16.66%) were bilateral (Figure 3).

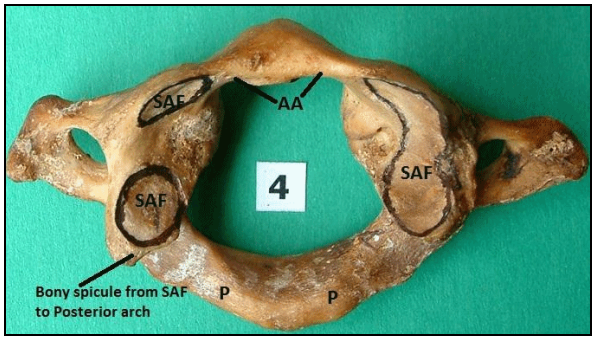

Figure 2A- Left partial posterior ponticulus (noted as A bony spicule extending from the superior articular facet (SAF) overhanging the posterior arch of atlas). SAF- Superior Articular Facet, P- Posterior Arch, AA- Anterior Arch

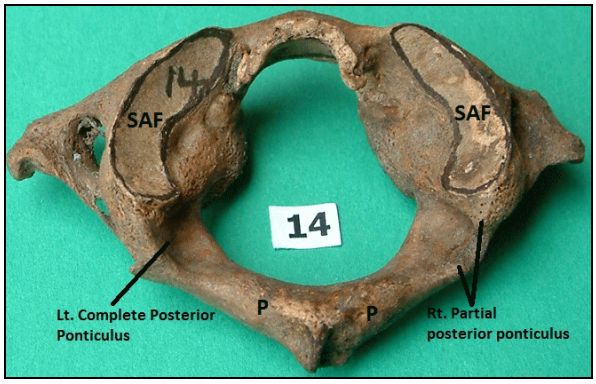

Figure 2B- Left complete posterior ponticulus and right partial posterior ponticulus**.** SAF- Superior Articular Facet, P- Posterior Arch.

Partial lateral ponticulus was seen as 2 (3.33%) cases on right side 3 (5%) on left side and no bilateral were observed.
One (1.66%) postero-latetal tunnel was also observed on the left side (Figure 4).
The difference in the localisation of the different types of bony outgrowths on right, left and bilateral sides was determined using Chi- Square test (χ^2), Degree of freedom (df) and p-value which was found to be x2=16.937; df=10; p=0.076; Not significant.

DISCUSSION

Origin of bridges (posterior and lateral bridgeand postero-lateral tunnels) is a matter of much debate and different workers have put forward many theories for their

development. The posterior bridge (retroarticular ring) was first reported by Macalister (1869). Later on its detailed morphology was studied by Macalister (1893) and Le Double (1912) and has drawn attention of many anatomists since then.

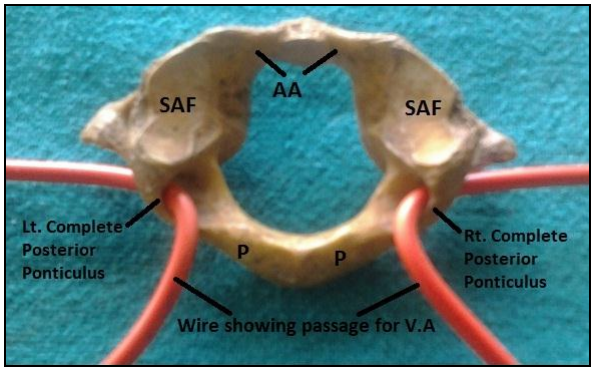

Figure 3- Showing bilateral complete posterior ponticuli. V.A- Vertebral Artery, SAF- Superior Articular Facet, P- Posterior Arch, AA- Anterior Arch

According to Macalister (1869), Allen (1879) and Cleland (1960), the formation of posterior bridge is simply a congenital characteristic due to persistence of the superior oblique process of other mammals. Le Double (1912) attributed the acquired ossification of ligaments induced by the pulsation of the vertebral artery and also added that such a bony ring cannot be a simple ossification of ligament but a regressive and disappearing morphological phenomenon. This theory is further proved by Lamberty and Zivanovic (1973) who observed bony rings in the atlases of two children's skeleton aged 2 and 4 years and proposed that ossification of a ligament does not occur in such young persons. Barge (1918) postulated an activation of special osteogenic potency existing in the region of cranio-vertebral junction. Selby et al (1955) and Saunders and Popovich (1977) believe that the posterior bridge has a substantial genetic basis and thus familial in nature. Pyo and Lowman (1959) and White and Panjabi (1978) convinced that posterior bridge is a late ossification of the lateral fibers of posterior atlanto-occipital membrane thus may be a result of ageing. Breathnach (1965) associated this bridging with ossification of oblique ligament of atlas. Von Torklus and Gele (1972) proposed that posterior bridge represent the occipital vertebra. Burlet (1913) concurs with the statement of Von Torklus and Gele (1972) that the posterior bridge develops from the dorsal arch of proatlas and belongs definitely to the manifestations of occipital vertebra.

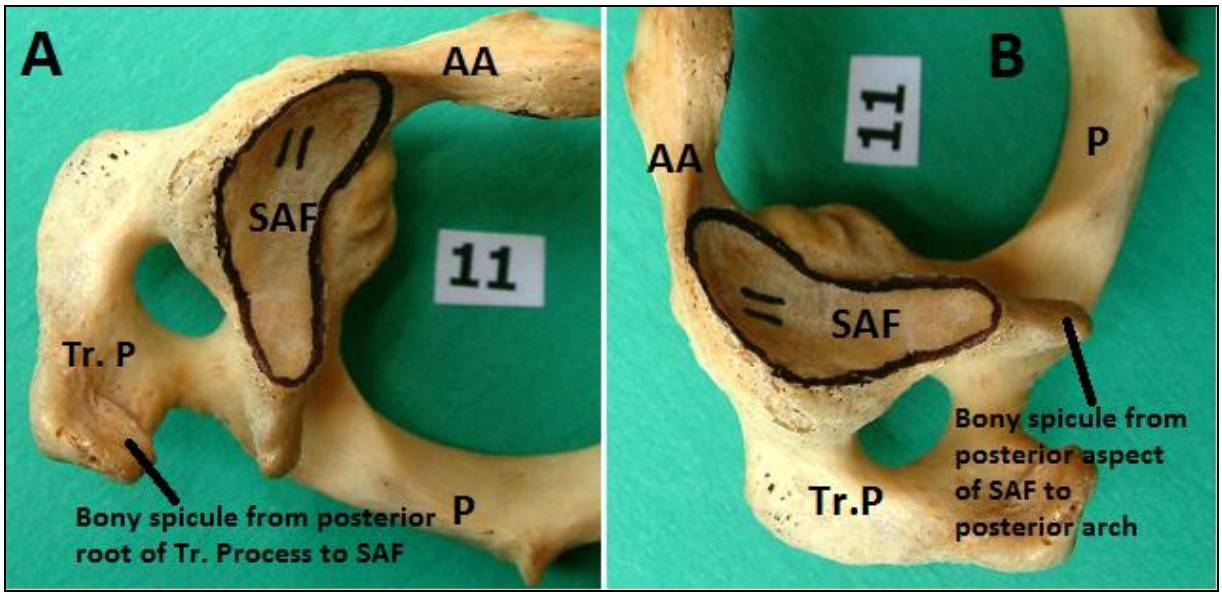

Figure 4A, B.- Superior view (a) and superolateral view (b) of atlas showing partial posterolateral tunnel as a combination of incomplete posterior and lateral bridges. Tr- Transverse process, SAF- Superior articular facet, A- Anterior arch, P- Posterior arch

Taitz and Nathan (1986) blamed external mechanical factors like custom of carrying heavy objects on head for the development of bridging on atlas. It was further supported by Paraskevas and Papaziogas (2005) who found a higher incidence of complete canal in labourers as compared with non labourers and also seen the higher incidence of incomplete foramen in 5-44 years of age. Stubbs (1992) encountered a complete foramen more in males and partial foramen in females. However on the contrary, Cakmak et al (2005) found a higher incidence of complete foramen in females.

The lateral bridge was first described by Macalister (1893) as a variety of post-glenoid process which was termed as gleno-transverse bony arch. According to Hayek (1927) which was later on supported by Von Torkulus and Gele (1972) that the lateral bridge develops from the material of lateral extension of proatlas and consequently belongs to manifestations of the occipital vertebra.

Sr No.	Authors	Year	Incidence		
			Posterior Bridge(Complete)	Posterior Bridge (Incomplete)	Lateral Bridge
1.	Le Double A F	1912	11.7%	-	1.8%
2.	Loth Niermirycz J	1916	7.4%	-	-
3.	Barge JAJ	1918	-	-	2.3%
4.	Hayek H	1927	10%	-	2.9%
5.	Toro I & Szepe L	1942	18%	-	3.5%
6.	Malhotra VK et al	1979	5.14%	-	0.80%
7.	Taitz & Nathan	1986	7.8%	25.9%	3.8%
8.	Prescher A	1997	11%	-	-
9.	Lamberty & Zivanovic	1973	15%	21.66%	-
10.	Radojevic & Negtovanic	1963	21%	2%	2.5%
11.	Mitchell J	1998a,b	9.8%	29.6%	12.24%
12.	Hasan et al	2001	6.57%	-	2%
13.	Dhall et al	1993	37.83%	-	13.50%
14.	Paraskevas & Papaziogas	2005	10.23%	24.43%	11.36%
15.	Le Minor JM	1997	18.3%	-	-
16.	Manjunath K Y	2001	11.7%	-	-
17.	Krishnamurthy et al	2007	8.33%	5.5%	-
18.	Serkan Simsek	2008	3.8%	5.6%	-
19.	Dahipale & Bahotee	2009	2%	18%	-
20.	Zambare & Reddy	2011	4%	12%	-
21.	Piplani Lalit M et al	2013	1 case	-	-
22.	Present study	2014	10%	13.33%	8.3%

Table 1 - Incidence of atlas bridges of human atlas vertebr

It is also hypothesized that incomplete retro-articular canal is the precursor of complete bony ring (Paraskevas and Papaziogas, 2005). This opinion has also been supported by Kendrick and Biggs (1963) who after an observation of two females with a unilateral incomplete bony ring found a developing unilateral radio-opaque complete ring over a period of 1 to 2 years. The incidence of complete and incomplete posterior and lateral bridges is depicted in Table 1.
Table 2 depicts the comparison of atlas bridges with Mitchell (1998) who gave 3 classes of atlas vertebrae based upon degree of formation of posterior and lateral bridges for the passage of third part of vertebral artery. In the present study, the left only type of complete bony ring has a higher incidence as compared to the right side in North Indians (Mitchell, 1998a). Mitchell (1998b) also worked on 147 samples of atlas vertebrae with lateral bridges but in our study no bilateral incomplete or complete lateral bridge was observed (Mitchell, 1998b). The number of lateral bridges occurring with retro-articular canal appears to increase with age after 40 years as a result of degenerative changes (Taitz and Nathan, 1986).

Atlas Bridges	Types / Class	Mitchell (1998a,b) SouthAfrican Population	Present Study (2013) North Indian Punjabi Population
Posterior Bridge	Class I	63.3%	71.66%
	Class II	26.9%	13.33%
	Class III	9.8% - 11.7% (Rt.) - 24.6% (Lt.) - 31.8% (Bl)	10%(12) - 25% (3) Rt. - 41.66% (5)Lt. - 16.66% (2) Bl
Lateral Bridge	Complete ring	12.24% (18)	-
	Incomplete ring	87.76% (129)	- 3.33% (2) Rt. - 5% (3) Lt.

Table 2 - Comparison of atlas bridges with Mitchell J, 1998a, b

Types Of sulcus/canalis arteriae vertebralis	Hasan et al (2001) U.P. Population						Present study (2014) North Indian Punjabi Population					
	Rt. Side		Lt. Side		Bilat.		Rt. Side		Lt. Side		Bilat.	
	N	%	N	%	N	%	N	%	N	%	N	%
Class I	-	-	-	-	166	47.40	4	6.66	4	6.66	18	30.00
Class II	-	-	-	-	150	42.90	8	13.33	6	10.00	14	23.33
Class III	3	0.86	4	1.14	4	1.14	2	3.33	2	3.33	6	10
Class IV	4	1.14	5	1.42	3	0.86	3	5	5	8.33	2	3.33
Class V	2	0.57	4	1.14	1	0.29	2	3.33	3	5.00	-	-
Class VI	2	0.57	2	0.57	-	-	-	-	1	1.66	-	-

Table 3 - Comparision of atlas bridges with hasan et al, 2001

Hasan et al (2001) also worked extensively on the subject and classified the atlas bridges in 6 classes as shown in Table 3. As depicted from the table 3 the vertebral artery ring of atlas in the present study was compared on the basis of study of Hasan et al (2001) and the most common was found to be the impression for vertebral artery. No bilateral lateral ponticuli were seen and only one partial postero-lateral tunnel was observed on the left side only. The difference in the localisation of the different types of bony outgrowths on right, left and bilateral sides was found to be statistically insignificant. ($x2=16.937$; $df=10$; $p=0.076$).

Our findings that bilateral retroarticular canal has the lowest incidence, the right type of retro-articular canal having an incidence of 5 % and left only type having higher incidence 8.33% and 3.33% bilateral type in our North Indian samples. These conclusions support the findings of Lamberty and Zivanovic (1973) who found bilateral type having the lowest incidence 3.3% and the left only type the highest incidence in a skeletal sample of 60 American whites. Our findings also concurs with the Paraskevas and Papaziogas (2005) who also found that bilateral bony canal has the lowest incidence 1.13%, the right only type of bony ring having an incidence of 2.84% and the left only type the higher incidence 5.11% in Northern Greek skeletal sample. The phenomenon of higher occurrence of left only type than the right only type can be attributed to the explanation due in part to unequal weight bearing as a result of more commonly left tilted head posture (Dhall et al, 1993). Owing to the right sided dominance of muscles of the body in right handers, the larger and consequently stronger sternocleidomastoid muscle would tend to tilt the head towards opposite side (Pande and Singh, 1971). It is also believed that atlas bridges are more common in individuals who sustain greater stress in the region of cranio-cervical junction (Taitz and Nathan, 1986).

In the present study the lateral bridges and postero-lateral tunnels were more commonly observed on the left side. These findings support the findings of Dhall et al (1993) who also observed an increased incidence of bridges on the left side and correlated with the larger superior articular facets on that side (Hasan et al, 2001).

According to Macalister (1869) a variable tongue shaped outgrowth known as postglenoid process arises from the hinder and outer lip of glenoid cavity which is present in 21% of the atlas vertebrae in some degree, becomes ossified and sometimes sufficiently large to convert that groove into a foramen forming a bridge over the vertebral artery and suboccipital nerve. Thus this bridge is chiefly formed by the extension of ossification into ligament from the post-glenoid end, where it is incomplete behind.

In the evolutionay history in primates, the prevalence of both types of bridges is very high in non-hominoids primates whereas it is relatively low in extant hominoids and hominoids and even lower in humans. This trend appears to correspond to postural changes in primates from quadrupedalism where head is supported by extensor muscles of neck and ligaments to bipedalism for example in man, where weight of head is borne by vertical loading of SAF of atlas and roof of the tunnel thus has disappeared. It is reported that the posterior bridge occurs in various mammals like chiropetra, carnivore, cetacean, pinnipedia, edentate artiodactyla (Le Double, 1912). However, almost all cases of Japanese macaques have a bilateral complete posterior bridge the development of which is demonstrated to be a normal process of growth. The lateral bridge starts to form later and more gradually than the posterior bridge (Yamamoto, 2006). However, the true oblique process is of common occurrence in monkey, bear, lion, leopard, sheep, deer and goat, etc (Macalister, 1869).

High incidence of this bony ring suggests that it may be of significance in aetiology of vertebro-basilar insufficiency presenting with dizziness, fainting and transient diplopia as many cases have been reported where surgical removal of bony bridges alleviate the symptoms of vertebro-basilar insufficiency (Taitz and Nathan, 1978). Ercegovac and Davidovic (1970) alleviated the symptoms of vertebrobasilar insufficiency by surgical removal of bony ring in eight cases. Cacciola et al (2004) while elaborating it further revealed that the vertebral artery occupies 57% of the vertebral artery groove over the lateral part of the posterior arch of atlas. When a foramen is formed over here, it produces a relatively tight situation of vertebral artery leading to giddiness on external neck movements due to vertebra-basilar insufficiency. Cakmak et al (2005) asserted that cervical spine radiography is a simple and useful technique to know the presence of arcuate foramen and should be considered if a patient comes with symptoms like pain in temporal region, pain in back of eye, vertigo, occipital headache, periodic photophobia, paresthesia of hands or sensation of pressure on hands. Moreover whiplash injuries a type of neck hyperflexion are very common nowadays, occurring during traffic accidents that may lead to rupture of the ligaments and posterior atlanto-occipital membrane resulting in ossification

procedure due to deposition of calcium salts in the formed haematoma at the rupture sites (McRae, 1999).

In an individual with a lateral bridge of atlas and an associated retroarticular canal may further results in increased compression of the vertebral artery and compromised blood flow during extreme rotation of head and neck as occurs in manipulation of cervical spine (Parkin et al, 1978).

Hence knowledge of quantitative anatomy of the vertebral artery groove will prove useful to surgeons performing operative procedures in this region and help in avoiding vascular complications.

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